Wet versus dry fluid protocols in adult patients undergoing unilateral orthopedic lower limb surgery under spinal anesthesia

Ragaa Herdan, Mennat-Allah Mahmoud Bakri, Essam Sharkawy Abdel-Allah

Anesthesia and Intensive Care Department, Faculty of Medicine, Assiut University, Egypt

Correspondence to Mennat-Allah Mahmoud Bakri MSc,
Demonstrator at Anesthesia and Intensive Care Department, Faculty of Medicine, Assiut University, Assiut, Egypt.
Postal code: 71515;
Mobile: +201090692006.
e-mail: Mennabakri291090@gmail.com

Received 22 September 2019
Revised 09 March 2020
Accepted 14 April 2020
Published 23 February 2021

Journal of Current Medical Research and Practice
2021, 6:70–75

Background
Optimal strategy for peri operative fluid therapy remains controversial and uncertain. We compared two different fluid administration protocols (dry/wet) on the hemodynamic variables in adult patients under spinal anesthesia. We hypothesized that both protocols had the same effect.

Patients and methods
A randomized controlled double-blind study was conducted in Assiut University Hospitals and was carried out on 80 adult patients scheduled for unilateral lower limb surgery under intrathecal anesthesia. Group I included 40 patients who were subjected to 'dry' approach of intraoperative 4–6 ml/kg/h of Ringer's lactate starting from conduction of intrathecal anesthesia. Group II included 40 patients who were subjected to 'wet' approach of intraoperative 18–20 ml/kg/h of Ringer's lactate starting from conduction of intrathecal anesthesia.

Results
Both groups are comparable and had no statistically significant differences regarding the demographic data, preoperative investigations, hemodynamic variables, and oxygen saturation. The wet group revealed insignificantly higher intraoperative blood loss. The total intravenous fluid intake was significantly higher in the wet group compared with the dry group (1860±599.77 vs. 716.66±295.75 ml, respectively; $P<0.001$). No major complications were observed during the whole study period.

Conclusion
The use of the terms 'wet' or 'dry' fluid administration strategies does not precisely define the optimal volume of fluid needed, and continuous monitoring of hemodynamics is essential.

Keywords:
dry/wet, fluid administration, lower limb surgery, spinal anesthesia

J Curr Med Res Pract 6:70–75
© 2021 Faculty of Medicine, Assiut University
2357-0121

Introduction

Intravenous hydration is a common practice to maintain effective blood volume and kidney perfusion. Appropriate hydration is important for the avoidance of acute kidney injury [1].

The best strategy for perioperative fluid therapy remains controversial and uncertain. A lot of debate surrounds strategies of perioperative fluid therapy regarding the type of fluids (colloid vs. crystalloid), the total volume (restrictive vs. liberal), and timing of administration of fluids guided by hemodynamic goals (goal directed vs. not goal directed) [2].

Giving a large amount of intravenous fluid preoperatively is a common clinical practice. Although fluid loading may result in expanding intravascular space, improving tissue perfusion or oxygenation [3], and reducing minor postoperative complications [4], excess fluid may also increase some perioperative complications [5].

Establishing the effect of excessive amount of fluid administration is difficult because the absolute amount of fluid administered varied substantially, making its conclusion difficult to implement in clinical practice [6]. Restriction of fluid has been used as part of fast-track surgery [7].

The hypothesis of this study was to compare the effect of two different fluid administration protocols on the hemodynamic variables in adult patients undergoing unilateral orthopedic lower limb surgery under intrathecal anesthesia.

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

Patients and methods

After approval by our faculty ethics committee (IRB no: 17100123), the study was registered in clinical trials (NCT03697330). An informed written consent was obtained from each patient before enrollment, and all patients were provided with complete information about the study and the techniques used. A flow diagram of both groups is shown in Fig. 1.

Study design and randomization: this double-blinded randomized controlled study was conducted in Assiut University Hospitals and carried on 80 adult patients, with American Society of Anesthesiologists (ASA) status I and II, and scheduled for unilateral lower limb orthopedic surgery under intrathecal anesthesia. Randomization was done using the sealed envelope method based on computer-generated list of random numbers. We achieved double blinding by masking the volume of fluid infused. The allocated fluid regimen was administered by an anesthesiologist not involved in patient assessments.

Sample size

Sample size calculation was carried out using G*Power 3 software program (Erdfelder, Faul, & Buchner, 1996). A total calculated minimal sample of 74 patients (raised to include 80 to compensate for dropouts; 40 patients in each group) was needed to detect the difference between preoperative and immediate postoperative blood pressure readings [based on previous literature (1–6)] with an error probability of 0.05 and 90% power on a two-tailed test.

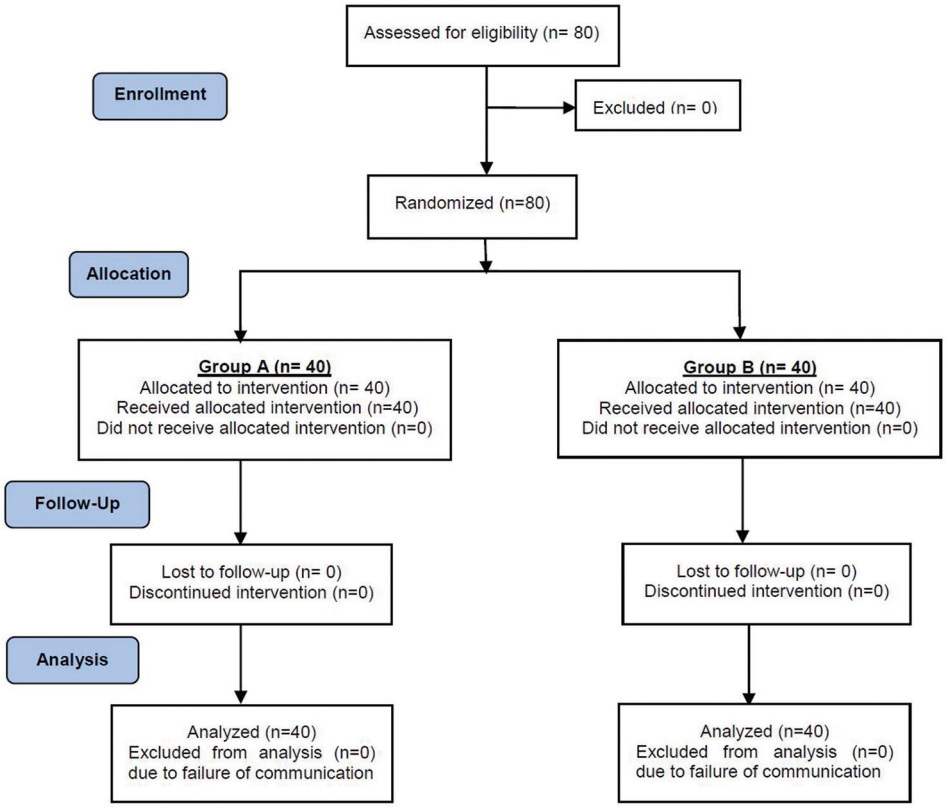
A total of 80 patients of both sex, aged 18–50 years, with ASA state I or II, and scheduled for unilateral orthopedic lower limb surgery were included in the study. Patients were excluded if they had hypersensitivity to any local anesthetics, bleeding diathesis, psychiatric disorders, pregnancy, chronic kidney disease, diabetes mellitus, chronic heart, lung or liver disease, burn injury, or morbid obesity.

Group I included 40 patients who were subjected to 'dry' approach of intraoperative 4–6 ml/kg/h of Ringer's lactate starting from conduction of intrathecal anesthesia. Group II included 40 patients who were subjected to 'wet' approach of intraoperative 18–20 ml/kg/h of Ringer's lactate starting from conduction of intrathecal anesthesia.

Anesthetic technique

All patients underwent preanesthetic checkup and the routine preoperative laboratory investigations were done. Preoperative fluid status was standardized for all

Figure 1



Flow diagram of the study groups.

patients (kept nil per mouth 6 h for solids and 2 h for water and clear liquids). After arriving to the operative room, pulse oximetry, electrocardiography, temperature probe, and noninvasive blood pressure monitor were applied. A large bore intravenous cannula (18 G) was inserted.

Under aseptic technique and local skin infiltration with 1% lidocaine, intrathecal anesthesia was performed at the L3–4 or L4–5 spinal interspace by 25 G spinal needle. After successful cerebrospinal fluid recognition, 15 mg heavy bupivacaine 0.5% mixed with 25 μg fentanyl was injected into the subarachnoid space. Once adequate anesthesia level to at least T10 dermatome was achieved, the operation was allowed to be started. An anesthesiologist unaware about the used protocol managed and assessed the patients.

Assessment

Vital signs including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean blood pressure (MBP), and arterial oxygen saturation (SpO_2) were recorded at baseline (5 min before conduct of spinal anesthesia), immediately after conduction of anesthesia, and then every 5 min till end of surgery. The level of sensory block was assessed before beginning of the surgery using an ice cube. Hypotension in the absence of surgical bleeding, defined as decrease in MBP to more than 20% of baseline values, was treated with 5 mg intravenous bolus of ephedrine. If hypotension persisted after 30 mg ephedrine, additional amounts of Ringer's lactate (5 ml/kg) was infused through the 18 G intravenous cannula. Blood loss (estimated by assessment of the suction bottles, sponges, and the surgical drapes and gowns) was replaced using crystalloids and blood as indicated. Each 1 ml of blood loss was supposed to be replaced by one ml of blood or 3 ml of isotonic saline NaCl 0.9%.

After finishing the surgery, patients were admitted to the postanesthesia care unit where they were monitored by an intensivist who was blinded to the study groups regarding immediate postoperative HR, SBP, DBP, MBP, SpO_2, respiratory rate, and recovery time of motor blockade (up to Bromage score of 2).

Then all patients were transferred to the ward where follow-up was done for 2 days postoperatively regarding the following:

(1) Analgesia: intravenous paracetamol 1 g/6 h regularly for 2 days and then on request.
(2) Early enforced mobilization: patients were allowed to mobilize, and training sessions were provided by a physiotherapist on day 1 postoperatively.
(3) Oral fluid intake was encouraged as early as possible.

Outcome measures: the primary outcome was the hemodynamic changes regarding the difference between preoperative and immediate postoperative blood pressure. Secondary outcomes included the difference between preoperative and immediate postoperative HR and SpO_2, the duration and type of surgery, total volume of intravenous infused fluids, estimated blood loss, and any complications such as hypotension, surgical wound edema, deep venous thrombosis, or wound infection.

Statistical analysis

Data were collected and analyzed using Statistical Package for the Social Science, SPSS version 20 (IBM Corporation, Armonk, NY, USA). Normally distributed numerical data were presented as mean ± SD, range, number, and percentage. Hemodynamic parameters were compared between both groups using the independent Student's *t* test, whereas the nonparametric data were compared using Mann–Whiney *U* test. Categorical variables (age, sex) were analyzed using χ^2 test. *P* value was statistically significant if less than 0.05.

Results

This study was conducted at Assiut University Hospitals between May 2017 and September 2018. It was carried on 80 adult patients (64 males and 16 females) who underwent unilateral orthopedic lower limb surgery using intrathecal anesthesia.

Demographic data and clinical characteristics of the studied patients are presented in Table 1. Both groups are comparable and had no statistically significant differences regarding age, sex, weight, height, BMI, and ASA status.

Mean age of the group I patients was 30.13 ± 7.89 years, and it included 31 males and nine females. However, the mean age of the group II patients was 30.40 ± 9.56 years, and it included 33 males and seven females.

Regarding BMI, 30% of group I patients and 22.5% of the group II patients were obese, the majority of both groups (50%) were overweight, whereas 20% of group I patients and 27.5% of group II patients had normal body weight. A total of 31 (77.5%) and nine (22.5%) patients in group I had ASA status I and II, respectively, whereas 32 (80%) and eight (20%) patients in group II had ASA status I and II, respectively.

Table 1 Demographic data and clinical characteristics of the two studied groups

Variables	Group I (*n*=40)	Group II (*n*=40)	*P*
Age (years)	30.13±7.89	30.40±9.56	0.79
Sex			
Male	31 (77.5)	33 (82.5)	0.39
Female	9 (22.5)	7 (17.5)	
Weight (kg)	80.87±11.81	81.15±9.53	0.90
Height (m)	1.69±0.06	1.70±0.07	0.55
BMI (kg/m^2)	28.11±3.88	28.09±4.42	0.42
Normal	8 (20)	11 (27.5)	
Overweight	20 (50)	20 (50)	
Obese >30	12 (30)	9 (22.5)	
ASA status			
I	31 (77.5)	32 (80)	
II	9 (22.5)	8 (20)	
Type of surgery			
Knee arthroscopy	19 (47.5)	25 (62.5)	
HTO	3 (7.5)	7 (17.5)	
Fracture tibia	14 (35)	8 (20)	
Fracture ankle	4 (10)	0	
Operative time (min)	85.45±28.09	89.90±25.89	0.42

Data are expressed in the form of mean±SD and n (%). ASA, American Society of Anesthesiologists; HTO, high tibial osteotomy. Group I included those who received dry protocol, whereas group II included those who received wet protocol. *P* value is significant if less than 0.05.

Table 2 Baseline laboratory data of the two studied groups

Variables	Group I (*n*=40)	Group II (*n*=40)	*P*
Hemoglobin (g %)	13.06±2.01	12.99±1.99	0.70
TLC (×10^3/ml)	6.42±1.13	6.94±1.02	0.37
Platelets (×10^3/ml)	238.22±76.79	250.09±47.07	0.70
PT (s)	12.07±0.94	12.26±0.82	0.22
INR	1.04±0.06	1.06±0.06	0.43
Blood urea (mg/dl)	4.06±1.22	4.22±1.10	0.73
Serum creatinine (mg/dl)	0.75±0.13	0.79±0.16	0.95
Sodium (µmol/l)	132.22±2.14	133.06±3.37	0.22
Potassium (µmol/l)	3.91±0.32	3.80±0.22	0.43

Data are expressed in the form of mean±SD. INR, international normalized ratio; PT, prothrombin time; TLC, total leucocyte count. Group I included those who received dry protocol, whereas group II included those who received wet protocol.P value is significant if less than 0.05.

Mean operative time in group I was 85.45 ± 28.09 min, whereas the mean operative time in group II was 89.90 ± 25.89 min, with no statistically significant difference between the two study groups ($P > 0.05$).

Baseline laboratory data in the two groups are presented in Table 2. It was noticed that both groups had no statistically significant differences regarding the baseline laboratory data ($P > 0.05$), including hemoglobin, total leukocyte count, platelets, prothrombin time, international normalized ratio, blood urea, serum creatinine, and sodium and potassium levels.

Both groups had no statistically significant differences regarding HR at different times ($P > 0.05$) (Table 3),

Table 3 Changes in heart rate (beats/min) in the two studied groups

Time	Group I (*n*=40)	Group II (*n*=40)	*P*
Preoperative	84.43±14.02	88.29±16.75	0.93
Intraoperative			
Before block	84.06±12.01	88.99±16.22	0.22
Immediate after block	84.86±11.23	85.46±13.06	0.89
At 10 min	77.56±11.09	78.22±13.22	0.34
At 20 min	76.33±10.98	74.01±12.57	0.30
At 30 min	74.01±12.49	72.16±12.96	0.07
At 40 min	74.22±13.99	70.99±11.09	0.39
At 50 min	75.03±13.99	73.22±11.35	0.93
At 60 min	75.30±13.22	71.78±12.08	0.12
After 60 min	73.11±10.34	73.99±11.27	0.43
At end of operation	77.30±11.38	76.98±11.29	0.58

Data are expressed in the form of mean±SD.Group I included those who received dry protocol, whereas group II included those who received wet protocol.*P* value is significant if less than 0.05.

Table 4 Changes in systolic blood pressure (mmHg) in the two studied groups

Time	Group I (*n*=40)	Group II (*n*=40)	*P*
Preoperative	128.50±11.44	131.29±13.03	0.22
Intraoperative			
Before block	131.36±12.45	134.06±13.22	0.14
Immediate after block	123.10±15.09	124.10±15.98	0.46
At 10 min	110.32±11.34	110.73 ±13.98	0.21
At 20 min	111.11±13.02	113.34±12.45	0.43
At 30 min	111.44±11.26	112.92±12.09	0.52
At 40 min	112.51±12.98	113.31±11.56	0.69
At 50 min	115.40±10.21	114.06±11.45	0.71
At 60 min	113.43±10.34	115.67±11.43	0.74
After 60 min	117.45±10.03	117.24±12.01	0.12
At end of operation	119.22±10.22	119.33±10.82	0.09

Data are expressed in the form of mean±SD.Group I included those who received dry protocol, whereas group II included those who received wet protocol.*P* value is significant if less than 0.05.

with comparable readings regarding the SBP (Table 4) and DBP (Table 5) correspondingly during the perioperative period. Regarding SpO_2 in the two studied groups (Table 6), both groups had no statistically significant differences at different times of the perioperative period ($P > 0.05$). Postoperative data regarding HR, blood pressure or oxygen saturation showed no statistically significant changes.

Table 7 shows that the estimated intraoperative blood loss in wet and dry group was 95 ± 24.01 and 70 ± 17.22, respectively, which was statistically insignificantly higher in the wet group. Intraoperative blood lose was minimal, as all the surgeries have been done under tourniquet. The total intravenous fluid intake was significantly higher in the wet group in comparison with that of the dry group (1860 ± 599.77 vs. 716.66 ± 295.75 ml, respectively) ($P < 0.001$). No patients developed intraoperative or postoperative complications during the hospital stay.

Table 5 Changes in diastolic blood pressure (mmHg) in the two studied groups

Time	Group I (*n*=40)	Group II (*n*=40)	*P*
Preoperative	74.53±11.34	79.25±10.32	0.12
Intraoperative			
Before block	74.98±12.22	74.23±10.34	0.78
Immediate after block	68.22±13.22	70.83±12.56	0.42
At 10 min	58.40±11.09	65.50±13.03	0.20
At 20 min	59.59±12.04	63.20±12.22	0.16
At 30 min	65.89±11.04	63.68±11.45	0.39
At 40 min	63.22±10.98	64.27±12.67	0.70
At 50 min	64.56±11.22	66.06±11.59	0.76
At 60 min	66.23±11.01	66.98±13.61	0.23
After 60 min	66.89±12.19	66.67±11.22	0.21
At end of operation	67.03±11.88	66.03±12.03	0.34

Data are expressed in the form of mean±SD. Group I included those who received dry protocol, whereas group II included those who received wet protocol. *P* value is significant if less than 0.05.

Table 6 Changes in arterial oxygen saturation (%) in the two studied groups

Time	Group I (*n*=40)	Group II (*n*=40)	*P*
Preoperative	99.47±0.90	99.55±0.89	0.23
Intraoperative			
Before block	99.70±0.78	99.46±1	0.12
Immediate after block	99.90±0.82	99.62±0.77	0.45
At 10 min	99.90±0.80	99.41±0.93	0.98
At 20 min	99.55±0.84	99.34±0.97	0.25
At 30 min	99.55±0.73	99.36±0.98	0.56
At 40 min	99.44±0.97	99.28±0.97	0.68
At 50 min	99.67±0.78	99.25±0.92	0.99
At 60 min	99.81±0.43	99.51±0.87	0.08
After 60 min	99.87±0.32	99.78±0.57	0.60
At end of operation	99.88±0.36	99.85±0.65	0.23

Data are expressed in the form of mean±SD.Group I included those who received dry protocol, whereas group II included those who received wet protocol.*P* value is significant if less than 0.05.

Table 7 Intraoperative total blood loss and fluid intake in the two studied groups

Variables	Group I (*n*=40)	Group II (*n*=40)	*P*
Estimated blood loss (ml)	70±17.22	95±24.01	0.14
Total intravenous fluid intake (Ringer's lactate)	716.66±295.75	1860±599.77	<0.001*

Data are expressed in the form of mean±SD.Group I included those who received dry protocol, whereas group II included those who received wet protocol.*P* value is significant if less than 0.05.

Discussion

It has been recommended that care taking with fluid therapy is similar as drug prescription owing to the adverse effects of fluids, regarding type, amount, and clinical context [8]. This was clarified by the 12th Acute Dialysis Quality Initiative where a framework for fluid therapy was proposed rather than a one-size-fits-all philosophy [9].

Administration of intravenous fluids in the patients depends on the requirements and type of fluid to be given. Intravenous fluids have quantitative and qualitative adverse effect depending up on the type of fluid and clinical settings. New evidence suggests that the choice of fluid replacement should be guided by patient-specific factors [10]. Both hypovolemia and hypervolemia are known to cause increased perioperative morbidity and mortality; therefore, assessment of the actual hemodynamic status of the patient can guide appropriate therapy [11].

Both 'dry' and 'wet' strategies of fluid infusion can lead to postoperative complications and morbidity. Dry protocol can lead to intestinal acidosis, postoperative ileus, and the translocation of bacteria and endotoxins into the vascular system, potentially causing sepsis or multiple system organ failure. However, the wet protocol can increase bowel edema, weight gain, and the incidence of postoperative ileus [12]. It was concluded that the restrictive protocol during optimization of hemodynamic parameters reduced major complications in older patients with comorbidities undergoing major surgery [13].

Definition of fluid overload is not simple. Most studies defined fluid overload by a percentage increase in the weight of the body from the day of admission to the ICU. This does, however, assume euvolemia on admission and ignores insensible losses as well as fluid administration in the pre-ICU setting [14]. There is a different effect of excess crystalloid versus colloid and blood product administration in volume overload [15].

The present study compared the effect of two protocols of fluid therapy (dry vs. wet) in adult patients who underwent unilateral orthopedic lower limb surgeries including knee arthroscopies, high tibial osteotomies, and tibia and ankle fracture surgeries using intrathecal anesthesia.

Regarding hemodynamics and intraoperative monitoring, hemodynamic stability was not difficult to maintain despite intraoperative fluid restriction. There was no statistically significant difference between the two studied groups regarding the HR, the SBP, the DBP, and the SpO_2 ($P < 0.05$). Estimated intraoperative blood loss was insignificantly higher in the wet group, but total fluid intake was significantly higher in such group in comparison with the dry group. We did not record any major complications during the study period.

This is contrary to the study of Nisanevich *et al.* [16], which evaluated 52 patients who underwent elective laparotomies. Patients were randomized to receive intraoperatively either a bolus of 10 ml/kg followed by 12 ml/kg/h of lactated Ringer's solution (LGP) or a continuous 4 ml/kg/h of the same solution with no bolus (RGP). The primary end point was mortality number or complication occurrence. The authors found a lower complication rate in patients of the RGP.

Significantly larger increases in body weight were noticed in the LPG compared with the RPG ($P < 0.01$).

In a double-blind study by Holte *et al*. [4], 48 relatively healthy patients underwent laparoscopic cholecystectomy. Patients were randomized to 15 ml/kg (restricted group) or 40 ml/kg (liberal group) intraoperative administration of lactated Ringer's solution. Intraoperative liberal group shows significantly improvement of nausea, general well-being, thirst, dizziness, drowsiness, fatigue, and balance function.

A total of 29 studies used various forms of hemodynamic monitors. It was concluded that with pre-emptive hemodynamic monitoring guiding therapy, the rate of surgical morbidity and mortality was significantly improved [17].

Brandstrup *et al*.[18] investigated restricted fluid regimen versus standard regimen in patients underwent colorectal surgery. All patients received an epidural for postoperative analgesia plus a general anesthetic. As for fluid management regimen, the restricted group did not receive fluid preloading before epidural placement or replacement of 'third space' loss. The restricted group had significantly reduced postoperative complications (33 vs. 51%, $P < 0.05$). No patients died in the restricted group compared with four deaths in the standard group (0 vs. 4.7%, $P < 0.12$).

Similarly, some investigators observed better preservation of cardiovascular stability in major surgeries with crystalloid administration regimen of 10–15 ml/kg/h [19]. Positive fluid balance has been associated with more complications and increased mortality in medical and surgical patients admitted to ICUs [20].

Limitations

We excluded the higher risk patients undergoing major surgeries, which may be considered in further studies. Late complications could have been missed because we followed patients only until hospital discharge. We did not include acute kidney injury in this manuscript, which might add to its value, and we recommend this in further studies.

Conclusion

The use of the terms 'wet' or 'dry' fluid administration strategies does not precisely define the optimal volume of fluid needed, and continuous monitoring of hemodynamics is essential. Either protocol was not associated with any major complications in patients with no risk.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Lobo SM, de Oliveira NE. Clinical review: what are the best hemodynamic targets for noncardiac surgical patients? Crit Care 2013; 17:210.
2. Bundgaard Nielsen M, Secher N, Kehlet H. 'Liberal' vs. 'restrictive' perioperative fluid therapy – a critical assessment of the evidence. Acta Anaesthesiol Scand 2009; 53:843–851.
3. Sear J. Kidney dysfunction in the postoperative period. Br J Anaesth 2004; 95:20–32.
4. Holte K, Klarskov B, Christensen DS, Lund C, Nielsen KG, Bie P, *et al*. Liberal versus restrictive fluid administration to improve recovery after laparoscopic cholecystectomy: a randomized, double-blind study. Ann Surg 2004;240:892.
5. Brandstrup B, Tønnesen H, Beier-Holgersen R, Hjortsø E, Ørding H, Lindorff-Larsen K, *et al*. Effects of intravenous fluid restriction on postoperative complications: comparison of two perioperative fluid regimens: a randomized assessor-blinded multicenter trial. Ann Surg 2003; 238:641.
6. Rahbari N, Zimmermann J, Schmidt T, Koch M, Weigand M, Weitz J. Meta-analysis of standard, restrictive and supplemental fluid administration in colorectal surgery. Br J Surg 2009; 96:331–341.
7. White PF, Kehlet H, Neal JM, Schricker T, Carr DB, Carli F, *et al*. The role of the anesthesiologist in fast-track surgery: from multimodal analgesia to perioperative medical care. Anesth Analg 2007;104:1380–1396.
8. Vincent J-L, De Backer D. Circulatory shock. N Engl J Med 2013; 369:1726–1734.
9. Myburgh JA, Mythen MG. Resuscitation fluids. N Engl J Med 2013; 369:1243–1251.
10. Perner A, Haase N, Guttormsen AB, Tenhunen J, Klemenzson G, Åneman A, *et al*. Hydroxyethyl starch 130/0.42 versus Ringer's acetate in severe sepsis. N Engl J Med 2012; 367:124–134.
11. Timothy E. Miller and Tong J. Gan. Section 3: Goal-directed fluid therapy. In: Robert G. Hahn. Clinical Fluid Therapy in the Perioperative Setting: second edition. Cambridge University Press 2011. p. 110–119.
12. Gan TJ. *Does fluid restriction improve outcomes of surgical patients? International Anesthesia Research Society*. 74th. Honolulu, Hawaii, USA: Clinical and Scientific Congress; 2010.
13. Lobo SM, Ronchi LS, Oliveira NE, Brandão PG, Froes A, Cunrath GS, *et al*. Restrictive strategy of intraoperative fluid maintenance during optimization of oxygen delivery decreases major complications after high-risk surgery. Crit Care 2011; 15:R226.
14. Ostermann M, Oudemans-van Straaten HM, Forni LG. Fluid overload and acute kidney injury: cause or consequence? Crit Care 2015; 19:443.
15. Raimundo M, Crichton S, Martin JR, Syed Y, Varrier M, Wyncoll D, *et al*.. Increased fluid administration after early acute kidney injury is associated with less renal recovery. Shock 2015; 44:431–437.
16. Nisanevich V, Felsenstein I, Almogy G, Weissman C, Einav S, Matot I. Effect of intraoperative fluid management on outcome after intraabdominal surgery. Anesthesiology 2005; 103:25.
17. Hamilton MA, Cecconi M, Rhodes A. A systematic review and meta-analysis on the use of preemptive hemodynamic intervention to improve postoperative outcomes in moderate and high-risk surgical patients. Anesth Analg 2011; 112:1392–1402.
18. Brandstrup B, Svensen C, Engquist A. Hemorrhage and operation cause a contraction of the extracellular space needing replacement – evidence and implications? A systematic review. Surgery 2006; 139:419–432.
19. Campbell I, Baxter J, Tweedie I, Taylor G, Keens S. IV fluids during surgery. Br J Anaesth 1990; 65:726–729.
20. Sakr Y, Vincent J-L, Reinhart K, Groeneveld J, Michalopoulos A, Sprung CL, *et al*. High tidal volume and positive fluid balance are associated with worse outcome in acute lung injury. Chest 2005; 128:3098–3108.